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Terms	Documents
l30 and ("LEDs")and (valve)	1

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DB Name	Query	Hit Count	Set Name
USPT	l30 and ("LEDs")and (valve)	1	L33
USPT	l30 and ("LEDs")	2	L32
USPT	l30 and ("light emitter")	0	L31
USPT	5583669	5	L30
USPT	4859034	9	L29
USPT	4859034	9	L28
USPT	5394254	5	L27
USPT	5444235	2	L26
USPT	l23 and ("valve")	0	L25
USPT	l23 and ("light valve")	0	L24
USPT	5557444	30	L23
USPT	L12 and ("light emitters")and (LIght valves)and (optical)and (illumination)	0	L22

USPT	L12 and ("light emitters")and (LIght valves)and (optical)and (LCD)	0	L21
USPT	L12 and ("light emitters")and (LIght valves)and (optical)	1	L20
USPT	L12 and ("light emitters")and (LIght valves)	1	L19
USPT	L12 and ("light emitters")and ("LIght valves")	0	L18
USPT	L12 and ("light emitters")	1	L17
USPT	L12 and (LEDs)and ("micro lens")	0	L16
USPT	L12 and (LEDs)and ("microlens")	0	L15
USPT	L12 and (LEDs)and (lens)	0	L14
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USPT	ali same zamani	11	L12
USPT	(((345/$4)!.ccls.)) and ("light valve")and ("point illumination") and (LEDs)and (lens)and (guides)	0	L11
USPT	(((345/$4)!.ccls.)) and ("light valve")and ("point illumination") and (LEDs)and (lens)	2	L10
USPT	(((345/$4)!.ccls.)) and ("light valve")and ("point illumination") and (LEDs)	2	L9
USPT	(((345/$4)!.ccls.)) and ("light valve")and ("point illumination") and ("light emitter")	0	L8
USPT	(((345/$4).ccls.)) and ("light valve")and ("point illumination")	3	L7
USPT	((345/$4).ccls.) and ("light valve")	350	L6
USPT	L1 and (LED)and ("light valves")	0	L5
USPT	L1 and (LED)and (character)	0	L4
USPT	L1 and (LED)and (valve)	0	L3
USPT	L1 and (LED)	1	L2
USPT	4899222	5	L1

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USPT	L12 and (LEDs)and ("micro lens")	0	L16
USPT	L12 and (LEDs)and ("microlens")	0	L15
USPT	L12 and (LEDs)and (lens)	0	L14
USPT	L12 and (LEDs)	2	L13
USPT	ali same zamani	11	L12
USPT	(((345/$4)!.ccls.)) and ("light valve")and ("point illumination") and (LEDs)and (lens)and (guides)	0	L11
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USPT	(((345/$4)!.ccls.)) and ("light valve")and ("point illumination") and (LEDs)	2	L9
USPT	(((345/$4)!.ccls.)) and ("light valve")and ("point illumination") and ("light emitter")	0	L8
USPT	(((345/$4).ccls.)) and ("light valve")and ("point illumination")	3	L7
USPT	((345/$4).ccls.) and ("light valve")	350	L6
USPT	L1 and (LED)and ("light valves")	0	L5
USPT	L1 and (LED)and (character)	0	L4
USPT	L1 and (LED)and (valve)	0	L3
USPT	L1 and (LED)	1	L2
USPT	4899222	5	L1

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L33: Entry 1 of 1 File: USPT Dec 10, 1996

DOCUMENT-IDENTIFIER: US 5583669 A
TITLE: Light valve apparatus, and projection display system and view-finder system employing said light valve apparatus

ABPL:
A light valve apparatus in which a first lens array, a second lens array, and a light valve are arranged sequentially from an incident light side, and a focal length of each of microlens elements for the first lens array is set to be shorter than a focal length of each of microlens elements for the second lens array, and the respective microlens elements of the second lens array are adapted to form real image corresponding to an imaginary object on a focal point of the respective microlens elements of the first lens array, on corresponding pixels of the light valve. By the first lens array, a plurality of very small light source images corresponding to the light source are formed, and light emitted from the plurality of very small light source images are incident upon the respective microlens elements of the second lens array so as to be projected onto the pixels of the light valve. Therefore, since the light incident upon openings of the light valve can be increased without thinning an incident side glass substrate of the light valve, substantial aperture ratio of the light valve apparatus may be improved. When the above light valve apparatus is used for a projection display system, projected images can be more brightened, while, if the above light valve apparats is applied to a view-finder system, it becomes possible to reduce the power consumption and also to improve brightness of the display images.

BSPR:
The present invention relates to a light valve apparatus, and a projection display system and a view-finder system employing said light valve apparatus.

BSPR:
Conventionally, there has been known a system in which optical images corresponding to video signals are formed on a light valve, and light is irradiated onto the optical images for projection thereof onto a large screen through magnification by a projection lens. Recently, there has been disclosed a projection display unit which employs a liquid crystal panel as a light valve, for example, in U.S. Pat. No. 5,042,929 to Tanaka et al., to which attention has been directed from the viewpoint that the projection unit may be made compact as a whole.

BSPR:
FIG. 25 shows an example of conventional light valve apparatuses in which a lens array plate is combined with the liquid crystal panel.

BSPR:
Accordingly, an essential object of the present invention is to provide a light valve apparatus which is capable of displaying bright projection images without reducing thickness of a glass substrate, even in the case where pixel pitch for a liquid crystal panel is small, and a projection display system and a view-finder system providing a bright display image at, a low power consumption by employing the light valve apparatus as referred to above.

BSPR:
Another object of the present invention is to provide a light valve apparatus, and a projection display system and a view-finder system employing said light valve apparatus, which are simple in construction and stable in functioning at high reliability, and can be readily manufactured at low cost.

BSPR:
In accomplishing these and other objects, according to one aspect of the present invention, there is provided a light valve apparatus which includes a light valve in which a plurality of pixels are arranged in a matrix pattern, a first lens array means in which a plurality of microlens elements are arranged in a matrix pattern similar to the pixel arrangement of the light valve, and which is disposed at an incident side of said light valve, and a second lens array means in which a plurality of microlens elements are arranged in a matrix pattern similar to the pixel arrangement of said light valve, and which is disposed between said light valve and said first lens array means. A focal distance of each of the microlens elements of said first lens array means is equal to or shorter than a focal distance of each of the microlens elements of said second lens array means, and the respective microlens elements of said second lens array means are adapted to form real image of an imaginary object on a focal point of the plurality of the microlens elements of said first lens array means, on the corresponding pixels of said light valve.

BSPR:
In another aspect of the present invention, the light valve apparatus further includes a third lens array means in which a plurality of microlens elements are arranged in a matrix pattern similar to that of the pixel arrangement of said light valve, and which is disposed between said first lens array means and said second lens array means. The respective microlens elements of said third lens array means are adapted to form imaginary objects on principal planes of the respective microlens elements of said first lens array, on principal planes of the plurality of the microlens elements of said second lens array means for said second lens array means.

BSPR:
In a further aspect of the present invention, it is so arranged that said light valve has the pixels thereof subjected to a square arrangement, and an optical axis of each of said microlens elements of said first lens array means passes through a middle point of a line connecting centers of neighboring two microlens elements of said second lens array means or a center of a square constituted by centers of the neighboring four microlens elements of said second lens array means.

BSPR:
In a still further aspect of the present invention, the arrangement is so made that said light valve has the pixels thereof subjected to a delta arrangement, and an optical axis of each of said microlens elements of said first lens array means passes through a middle point of a line connecting centers of neighboring two microlens elements of said second lens array means or a center of a triangle constituted by connecting centers of the neighboring three microlens elements of said second lens array means.

BSPR:
In another aspect of the present invention, there is provided a projection display system which includes a light source, a light valve apparatus upon which light emitted from said light source is incident and in which optical images are formed according to video signals, and a projection lens for projecting said optical images onto a screen, with any one of the light valve apparatuses being employed as a light valve means.

BSPR:
In still another aspect of the present invention, there is provided a view-finder system which includes a light source, a light valve apparatus upon which light emitted from said light source is incident and in which optical images are formed according to video signals, and a magnifying lens for

magnifying said optical images, with any one of the above light valve apparatuses being employed as a light valve means.

BSPR:
By the arrangements according to the present invention as described so far, an improved light valve apparatus with a large aperture ratio may be realized without any restriction to the light valve, and moreover, by employing this light valve apparatus, there are such favorable effects that a projection display system with bright projection images, and a view-finder system having bright display images at a low power consumption can be advantageously provided.

DRPR:
FIG. 1 is a schematic perspective diagram of a model for explaining functions of a light valve apparatus according to the present invention,

DRPR:
FIG. 8 is a fragmentary side sectional diagram showing on an enlarged scale, construction of a light valve apparatus according to a first embodiment of the present invention,

DRPR:
FIG. 9 is a schematic perspective diagram showing construction of a light valve apparatus according to a first embodiment of the present invention,

DRPR:
FIG. 12 is a fragmentary side sectional view showing on an enlarged scale, a light valve apparatus according to a second embodiment of the present invention,

DRPR:
FIG. 13 is a schematic perspective diagram showing construction of a light valve apparatus according to a second embodiment of the present invention,

DRPR:
FIG. 15 is a schematic fragmentary side sectional diagram showing construction of a light valve apparatus according to another embodiment of the present invention,

DRPR:
FIG. 16 is a schematic perspective diagram showing construction of a light valve apparatus according to another embodiment of the present invention,

DRPR:
FIG. 17 is a schematic fragmentary side sectional diagram showing construction of a light valve apparatus according to a third embodiment of the present invention,

DRPR:
FIG. 18 is a schematic perspective diagram showing construction of a light valve apparatus according to a third embodiment of the present invention,

DRPR:
FIGS. 19(a) and 19(b) are schematic perspective diagrams showing construction of light valve apparatuses each according to another embodiment of the present invention,

DRPR:
FIGS. 20(a) and 20(b) are schematic perspective diagrams showing constructions of light valve apparatuses each according to still another embodiment of the present invention,

DRPR:
FIGS. 21(a) and 21(b) are schematic perspective diagrams showing constructions of light valve apparatuses each according to further embodiment of the present

invention,

DRPR:
FIGS. 22(a) and 22(b) are schematic perspective diagrams showing construction of light valve apparatuses each according to still further embodiment of the present invention,

DRPR:
FIG. 25 is a schematic fragmentary side sectional diagram showing on an enlarged scale, construction of a conventional light valve apparatus (already referred to).

DEPR:
Before describing embodiments according to the present invention, principle for a light valve apparatus according to the present invention will be explained hereinbelow.

DEPR:
Referring now to the drawings, there is shown in FIG. 1, a model of a light valve apparatus according to the present invention, in which a first lens array means 71, a second lens array means 72, and a light valve 73 are sequentially disposed in that order from a light incident side. Here, it is assumed that each of the light valve 73, the first lens array means 71, and the second lens array means 72 is very thin, with air present in spaces therebetween. The light valve 73 has its pixels 74 arranged in a square pattern. In the first lens array means 71 and the second lens array means 72, square microlens elements 75 and 76 are arranged also in a square pattern respectively, and there is no non-lens region in any of the lens array means 75 and 76. It is assumed that all of the microlens elements 75 and 76 are thin and ideal lenses without any aberration. It is also assumed that pitches of the microlens elements 75 and 76 for the first lens array means 71 and the second lens array means 72 are exactly the same as the pitch of the pixels 74 for the light valve 73, and an optical axis 77 of each of the microlens element 75 and an optical axis 78 of the corresponding microlens element 76 are aligned with each other, and that each of the optical axes 77 and 78 passes through a center 79 of the pixel 74 for the light valve 73.

DEPR:
An optical path diagram corresponding to FIG. 1 is shown in FIG. 2. Upon incidence of light 80 from a light source (not shown here) on the first lens array means 71, each of the microlens elements 75 of the first lens array means 71 forms a very small real image 82 corresponding to the light source on each focal point 81. In other words, a first very small light source group 83 is formed at the emitting side of the first lens array means 71. Each of the microlens elements 76 of the second lens array means 72 forms an equal size real image 84 of the very small light source 82 rotated through 180.degree.. In other words, a second very small light source group 85 is formed at the emitting side of the second lens array means 72. The pitch of the first very small light source group 83 and the pitch of the second very small light source group 85 are equal to each other. In the case where the optical axis 77 of each of the microlens elements 75 is aligned with the optical axis 78 of the corresponding microlens element 76, the second very small light source group 85 formed by the respective microlens elements 76 entirely overlaps the respective very small light sources 84. When the pixel pitch of the light valve 73 is equal to the pitch of the second very small light source group 85, the respective pixels 74 of the light valve 73 can be overlapped with the respective very small light sources 84 of the second very small light source group 85.

DEPR:
If a distance from a focal point 81 to a principal point of the microlens element 76 is longer than a focal distance of the microlens element 75, light emitted from one microlens element 75a of the first lens array means 71 is incident upon the plurality of microlens elements 76a, 76b and 76c of the second lens array means 72, and the light emitted therefrom is incident upon

any of the pixels of the light valve 73. Thus, upon one pixel of the light valve 73, light is incident from the plurality of the microlens elements 76a, 76b and 76c of the second lens array means 72.

DEPR:
Furthermore, a model of the light valve apparatus in the case where a third lens array according to the present invention has been added is shown in FIG. 3, in which the first lens array means 71, the second lens array means 72, a third lens array means 91 and the light valve 73 are disposed in that order from an incident side. Here, it is also assumed that each of the light valve 73, the first lens array means 71, and the second lens array means 72 and the third lens array means 91 is very thin, with air present in the spaces therebetween. The constructions of the light valve 73, the first lens array means 71, and the second lens array means 72, and the arrangements of the respective pixels 74, and the respective microlens elements 75 and 76 are the same as those in FIG. 1. In the third lens array means 91, square microlens elements 92 are arranged in a square form respectively, and there is no non-lens region therein. It is assumed that all of the microlens elements 92 are thin and ideal lenses without any aberration. It is also assumed that pitch of the microlens elements 92 for the third lens array means 91 is exactly the same as the pixel pitch of the light valve 73, and an optical axis 93 of each of the microlens elements 92 for the third lens array means 91, is aligned with the corresponding optical axis 77 of each of the microlens elements 75 for the first lens array means 71, and the corresponding optical axis 78 of each of the microlens elements 76 for the second lens array means 72.

DEPR:
In an optical path diagram in FIG. 4 corresponding to FIG. 3, light 94 incident from the light source forms, by each of the microlens elements 75 of the first lens array means 71, a very small real image 82 corresponding to the light source on each focal point 81. The third lens array means 91 is so disposed that the very small light source images 82 by the respective microlens elements 75 for the first lens array means 71 are formed on the principal plane of the respective microlens elements 92, and accordingly, the images of the very small light source 82 formed on the principal plane of each of the microlens elements 92 of the third lens array means 91 is formed on each of the pixels of the light valve 73 by each of the microlens elements 76 of the second lens array means 72.

DEPR:
FIG. 5 shows an optical path diagram corresponding to FIGS. 3 and 4. Each of the microlens elements 92 of the third lens array means 91 forms the image of an imaginary object on the principal plane of each of the microlens elements 75 for the first leans array means 71, on the principal plane of each of the microlens elements 76 of the second lens array means 72, whereby the light incident upon each of the microlens elements 75 of the first lens array 71 and passing through the end portion 96 of the very small light source 82 formed on the focal point 81 thereof, is incident upon the principal plane,of each of the microlens elements 76 for the second lens array means 72 by each of the microlens elements 92 from the third lens array means 91. Accordingly, the light rays from the first very small light source image group formed by each of the microlens elements 75 of the first lens array 71 are incident upon the corresponding microlens element 76 for the second lens array means 72 so as to form a second very small light source image 84, and the light from the end portion 96 of the very small light source 82 can be incident upon each of the pixels 74 of the light valve 73.

DEPR:
In the models as shown in FIGS. 1 and 3, although c is restricted by the light valve 73, there is no factor which will restrict a+b. Therefore, the focal length f.sub.1 of the first lens array means 71 can be shortened, as a result of which the size of each of the very small light sources 84 of the second very small light source group 85 is also reduced. Meanwhile, as described above, the light rays emitted from the first lens array means 71 entirely

reach all of the pixels 74 of the light valve 73 through the plurality of the microlens elements 76 of the second lens array means 72, and substantial aperture ratio of the light valve apparatus as shown in FIG. 1 may be improved. If all the light rays emitted from the respective pixels of the light valve are incident upon the projection lens, the projected image will become brighter.

DEPR:
FIGS. 6 and 7 are optical path diagrams representing general cases in which light is incident upon one pixel of the light valve from the plurality of the microlens elements of the second lens array means.

DEPR:
According to the present invention, even in the case where the distance from the incident side face of the light valve to the light valve layer can not be shortened, by employing the two lens array means as shown in the model of FIG. 1, or three lens array means as shown in the model of FIG. 3, the light valve apparatus with a high substantial aperture ratio can be realized. When this light valve apparatus is employed for a projection display system, bright projection images may be obtained. Moreover, if the light valve apparatus of the present invention is used for a view-finder system, bright display images can also be obtained.

DEPR:
It is to be noted here that in the foregoing embodiments, although description given with respect to the case where the pixels of the light valve are arranged in the square shape, and the optical axis of each of the microlens elements for the first lens array means is aligned with that of each of the microlens elements for the second lens array means, and also, with that of each of the microlens elements for the third lens array means, the present invention is not limited in its application to the above case alone, but the intended effect of the present invention may be obtained even in the case where the pixels of the light valve are arranged for example, in a delta form or the relation of the optical axis is different from the above case, if the second very small light source group by each of the microlens elements for the second lens array means is entirely overlapped.

DEPR:
There is shown in FIG. 8, the construction of a light valve apparatus according to a first embodiment of the present invention.

DEPR:
In FIG. 8, the light valve apparatus of the present invention generally includes an incident side polarizing plate 101, a first lens array plate 102, a second lens array plate 103, a liquid crystal panel 104, and an emitting side polarizing plate 105 sequentially arranged in that order from the incident side as shown.

DEPR:
In FIG. 10, the projection display system generally includes a light source 131, a field lens 135, a light valve apparatus 136, a projection lens assembly 137 having an auxiliary projection lens 139 and a main projection lens 140, and a projection screen 138.

DEPR:
The light valve apparatus 136 is similar to that as shown in FIGS. 8 and 9, and includes the incident side polarizing plate 101, first lens array plate 102, second lens array plate 103, liquid crystal panel 104, and emitting side polarizing plate 105 sequentially disposed from the incident side.

DEPR:
Light emitted from the light source 131 passes through the field lens 135 so as to be incident on the light valve apparatus 136, and light outgoing therefrom is incident upon the projection lens assembly 137. Thus, the images formed on the liquid crystal panel 104 are magnified and projected onto the

projection screen 138 by the projection lens assembly 137. The field lens 135 is used for directing light incident upon the pixels around the liquid crystal panel 104 from the light source 131, to be perpendicular to the liquid crystal layer 108 (FIG. 8). The projection lens assembly 137 constituted by the auxiliary lens 139 disposed at the emitting side of the liquid crystal panel 104 and the main projection lens 140, has an aperture ratio of F3.5. The auxiliary lens 139 has for its object to make the principal light rays transmitted through all the pixels of the liquid crystal panel 104, perpendicular to the liquid crystal layer 108. Thus, light advancing along the optical axis 122 of the microlens element 116 of the first lens array plate 102 passes through the optical axis 123 of the corresponding microlens element 119 of the second lens array plate 103, and is incident upon the center 124 of the corresponding pixel 113 of the liquid crystal panel 104.

DEPR:
Referring back to FIG. 8, light rays 125 emitted from the light source 131 (FIG. 10) are incident on the first lens array plate 102. On the focal point 126 of each of the microlens elements 116 of the first lens array plate 102, a very small real image corresponding to the opening portion of the concave mirror 133 is formed. The respective microlens elements 119 of the second lens array plate 103 form the plurality of very small light sources on the liquid crystal layer 108 of the liquid crystal panel 104 at an equal size. The focal length f.sub.1 of the microlens element 116 for the first lens array plate 102, and the focal length f.sub.2 of the microlens element 119 for the second lens array plate 103 are adapted to satisfy the conditions of the equation (5) referred to earlier. Therefore, light emitted from one microlens element 116a for the first lens array plate 102 is incident on nine microlens elements 119a, 119b and 119c for the second lens array plate 103, and light rays emitted from the nine microlens elements 119a, 119b and 119c are respectively incident upon the pixels, 113a, 113b and 113c of the liquid crystal panel 104. On one pixel 113d of the liquid crystal panel 104, incident light rays from neighboring nine microlens elements 119d, 119e and 119f of the second lens array plate 103 are incident. It is so arranged that light rays emitted from the liquid crystal panel 104 are all incident on the projection lens assembly 137. On the light valve apparatus 136, optical images are formed as the variation of the transmittance according to the video signals. Such optical images are magnified and projected by the projection lens assembly 137, whereby enlarged projection images in black and white are displayed on the projection screen.

DEPR:
In the case where light rays emitted from the light source 131 and incident upon one microlens element 116 for the first lens array 102 are all incident upon the projection lens 137, and substantial aperture ratio of the light valve apparatus 136 may be represented by a ratio of areas on the lens face of all the microlens elements, to the area for the all region of the first lens array plate 102. The brightness at the image center of the projected image is increased by a ratio of the substantial aperture ratio, with respect to the actual aperture ratio of the liquid crystal panel.

DEPR:
In FIG. 11, a light source 151 includes a lamp 152, a concave mirror 153, and a filter 154. The lamp 152 is of a metal halide lamp, and radiates light rays containing color components for three primary colors. The concave mirror 153 is made of glass having a reflecting face 155 in a parabolic form, on which a multi-layered film transmitting infrared rays and reflecting visible light is deposited. The filter 154 is made of a glass substrate on which a multi-layered film transmitting visible light and reflecting infrared rays and ultraviolet rays is deposited. An optical axis 156 of the concave mirror 153 is directed in a horizontal direction, and the lamp 152 is disposed with its lamp axis aligned with the optical axis 156. Radiation light of the lamp 152 is converted into light close to parallel light rays from which infrared rays are eliminated through reflection by the concave mirror 153, and is emitted as visible light, with infrared rays and ultraviolet rays being removed therefrom by being transmitted through the filter 154. Light emitted from the light

source 151 is separated into primary colors of red, green and blue by a color separation optical system constituted by two dichroic mirrors 157 and 158 and a flat mirror 159. The respective primary colors are each transmitted through field lenses 160, 161 and 162 so as to be incident on light valve apparatuses 163, 164 and 165.

DEPR:
The respective light valve apparatuses 163,164 and 165 have the constructions similar to those as described earlier with reference to FIG. 8, and respectively include the incident side polarizing plates 166, 167 and 168, first lens array plates 169, 170 and 171, second lens array plates 172, 173 and 174, liquid crystal panels 175, 176 and 177, and emitting side polarizing plates 178, 179 and 180 as combined sequentially from the side of the light source. On each of the light valve apparatuses 163, 164 and 165, an optical image as variation of transmittance is formed according to the video signals respectively. Light rays emitted from the light valve apparatuses 163, 164 and 165 are composed into one light ray by a color combining optical system in which dichroic mirrors 184 and 185 and a flat mirror 186 are combined, after having been transmitted through auxiliary lenses 181, 182 and 183 respectively, and the composed light is incident upon a main projection lens 187.

DEPR:
The main projection lens 187 functions as a projection lens by being combined with the auxiliary lenses 181, 182 and 183, which are employed to allow the principal light rays of the projection lens 187 to pass through the liquid crystal layer perpendicularly, i.e., to improve so-called "telecentric" characteristic. Thus, the optical images formed on the three light valve apparatuses 163, 164 and 165 are magnified and projected by the main projection lens 187 onto a projection screen (not shown) located at a distant position.

DEPR:
Upon experiments carried out on the projection display apparatus as shown in FIG. 11 trially produced, projection images brighter than those in the case where the lens array plates were not employed, could be obtained. The uniformity of the image quality was also favorable except for faulty portions clearly attributable to the light valve apparatuses.

DEPR:
FIG. 12 shows a light valve apparatus according to a second embodiment of the present invention, which generally includes an incidence side polarizing plate 201, a lens array plate 202, a liquid crystal panel 203, and an emitting side polarizing plate 204 sequentially disposed in that order from the incident side.

DEPR:
When the light valve apparatus for the projection display system described earlier with reference to FIG. 10 is replaced by the light valve apparatus of FIG. 12, a projection image in full color can be obtained. As a result of experiments, brightness in the vicinity of the central portion of the projected image became about 1.5 times that in the case where the lens array plate was not provided.

DEPR:
Subsequently, an embodiment in which the light valve apparatus of the present invention has been applied to a view-finder system will be explained with reference to FIG. 14.

DEPR:
In FIG. 14, the view-finder system generally includes a casing 240, and a light valve apparatus 231, light source 236, and an eye-piece 239 which are accommodated in said casing 240 as described hereinbelow.

DEPR:

Although different in the dimensions of respective parts, the light valve apparatus 231 has the construction similar to that described earlier with reference to FIG. 12, and is constituted by an incident side polarizing plate 232, a lens array plate 233, a liquid crystal panel 234, and an emitting side polarizing plate 235 sequentially disposed in that order from the incident side. The liquid crystal panel 234 is of a TFT liquid crystal panel employing the TN liquid crystal similar to that described earlier with reference to FIG. 12, and incorporated with a color filter in a mosaic form. The display size is of 0.7 inch, and an image in full color is displayed.

DEPR:
The light source 236 is constituted by a lamp 237 and a condenser lens 238. The lamp 237 is of a fluorescent lamp with a diameter of 7 mm and a length of 20 mm to be turned on by D.C., and light irradiated from the lamp 237 is converted into a light ray with a narrow directivity by the condenser lens 238 so as to be incident upon the light valve apparatus 231, and light emitting therefrom is further incident on the eye-piece 239. When an observer (not shown) looks into the eye-piece 239, a magnified virtual image of the image on the light valve apparatus 231 can be seen. For the lamp 237, a light source of a high brightness with a small light emitting member such as an LED, halogen lamp, cathode ray tube or the like may be employed.

DEPR:
In the view-finder system as shown in FIG. 14, by employing the lens array, the substantial aperture ratio of the light valve apparatus is increased, and consequently, light utilizing efficiency can also be raised. Accordingly, power consumption of the lamp may be reduced, and the continuous using time in one charging of a battery is prolonged as compared with the case where the lens array is not employed.

DEPR:
Reference is made to FIG. 15 showing the construction of a light valve apparatus according to a third embodiment of the present invention.

DEPR:
In FIG. 15, the light valve apparatus of the present invention generally includes an incident side polarizing plate 301, a first lens array plate 307, second lens array plate 308, a liquid crystal panel 305, and an emitting side polarizing plate 306 sequentially arranged in that order from the incident side as shown.

DEPR:
When the light valve apparatus of the projection display system referred to earlier with reference to FIG. 10 is replaced by the light valve apparatus as shown in FIG. 15, projection images may be obtained.

DEPR:
As shown in FIG. 15, light rays 330 emitted from the light source are incident on the first lens array plate 302. On the focal point 331 of each of the microlens elements 317 of the first lens array plate 302, a very small real image corresponding to the opening of the concave mirror of the light source is formed. The respective microlens elements 321 of the second lens array plate 303 form the plurality of very small light sources on the liquid crystal layer 311 of the liquid crystal panel 305 at an equal size. The focal length f.sub.1 of the microlens element 317 for the first lens array plate 302, and the focal length f.sub.2 of the lens element 321 for the second lens array plate 303 are adapted to satisfy the conditions of the equation (5) referred to earlier. Therefore, light emitted from one lens element 317a for the first lens array plate 302 is incident on nine lens elements 321a, 321b and 321c for the second lens array plate 303, and light rays emitted form the nine lens elements 321a, 321b and 321c are respectively incident upon the pixels 314a, 314b and 314c of the liquid crystal panel 305. On one pixel 314d of the liquid crystal panel 305, incident light rays from neighboring nine microlens elements 321d, 321e and 321f of the second lens array plate 303 are incident. It is so arranged that light rays emitted from the liquid crystal panel 305

are all incident on the projection lens. On the light valve apparatus, optical images are formed as the variation of the transmittance according to the video signals. Such optical images are magnified and projected by the projection lens assembly, whereby enlarged projection images in black and white are displayed on the projection screen.

DEPR:
In the case where light rays emitted from the light source and incident upon one lens element 317 for the first lens array 302 are all incident upon the projection lens, substantial aperture ratio of the light valve apparatus may be represented by a ratio of areas on the lens face of all the microlens elements, to the area for the all region of the first lens array plate 302. The brightness at the image center of the projected image is increased by a ratio of the substantial aperture ratio, with respect to the actual aperture ratio of the liquid crystal panel. Furthermore, high quality image may be displayed on the projection screen, since it is not necessary to reduce the thickness of the incident side glass substrate 309 of the liquid crystal panel 305, as the same case of FIG. 8.

DEPR:
Projected image in full color may also be obtained when the light valve apparatus for the projection display system in FIG. 11 is replaced by the light valve apparatus of FIG. 15. In this case, projected images brighter than those in the case where two lens array plates are not employed, could be obtained.

DEPR:
In FIG. 17, there is shown the construction of a light valve apparatus according to a fourth embodiment of the present invention.

DEPR:
In FIG. 17, the light valve apparatus of the present invention generally includes an incident side polarizing plate 351, a first lens array plate 352, a second lens array plate 353, a liquid crystal panel 354, and an emitting side polarizing plate 355 sequentially arranged in that order from the incident side as shown. The liquid crystal panel 354 is similar in construction, to that described earlier with reference to FIG. 12.

DEPR:
When the light valve apparatus for the projection display system described earlier with reference to FIG. 10 is replaced by the light valve apparatus of FIG. 17, a projection image in full color can be obtained.

DEPR:
Hereinbelow, a further embodiment in which the light valve apparatus of the present invention has been applied to the view-finder system will be described with reference to FIG. 14. Although different in the dimensions of each parts, the light valve apparatus generally has the construction similar to that in FIG. 17, and includes the incident side polarizing plate 351, the first lens array plate 352, the second lens array plate 353, a liquid crystal panel 354, and an emitting side polarizing plate 355 sequentially arranged in that order from the incident side as shown (indicated by numerals in parentheses). The liquid crystal panel 354 is similar to that of the light valve apparatus described earlier with reference to FIG. 14.

DEPR:
In the case where the light valve apparatus of the view finder system as shown in FIG. 14, is replaced by the above light valve apparatus, magnified images in full color may be observed.

DEPR:
Subsequently, other embodiments of the light valve apparatus according to the present invention will be described.

DEPR:

The lens arrays which play an important part in the light valve apparatus according to the present invention require supporting means, therefor. Besides the embodiments as described so far, there may be adopted an arrangement in which a glass substrate is disposed close to the incident side of the liquid crystal panel, and a first lens array is formed on the incident side face of said glass substrate, with a second lens array being formed on an incident side face of an incident side glass substrate of the liquid crystal panel. Meanwhile, in the case where a third lens array is to be employed, it may be, for example, so arranged that, a third glass substrate is disposed at an incident side glass substrate of a liquid crystal panel, and a second glass substrate is disposed at an incident side of a third glass substrate, while a first glass substrate is disposed at an incident side of a second glass substrate, and a first lens array is formed at an emitting side face of the first glass substrate, and a third lens array is formed on an emitting side face of the second glass substrate, with a second lens array being formed on the emitting side face of the third glass substrate. Moreover, it is also possible to employ an arrangement in which a second lens array is formed at an incident side face of an incident side glass substrate of liquid crystal panel, and a second glass substrate is disposed at an incident side of a second lens array, while a first glass substrate is disposed at an incident side of a second glass substrate, while a third lens array is formed at an incident side of a second glass substrate, and a first lens array is formed at any of the incident side or emitting side face of the first glass substrate. Similarly, another arrangement which may be employed is such that a second glass substrate is disposed at an incident side of an incident side glass substrate of a liquid crystal panel, and a first glass substrate is disposed at an incident side of a second glass substrate, while a first lens array is formed on an incident side face of the first glass substrate, with a third lens array formed on an emitting side face thereof, and a second lens array is formed on an emitting side face of the second glass substrate. Moveover, it may be so arranged that a second lens array is formed on an incident side face of an incident side glass substrate of the liquid crystal panel, and a glass substrate is disposed at an incident side of the second lens array, while a first lens array is formed on the incident side face of the glass substrate, and the third lens array is formed on the emitting side face thereof.

DEPR:
In both of the light valve apparatus and the light valve, besides the manufacturing method of the lens array plates as described earlier with reference to the first embodiment, there has been conventionally proposed a method in which refractive index distribution lens is formed on the surface of a glass substrate by the ion exchange, selective diffusion or the like as disclosed, for example, in Japanese Patent Laid-Open Publication Tokkaihei No. 2-302726 or a method in which transparent thermoplastic resin is overlapped on a glass substrate for forming lenses by heat molding.

DEPR:
It is to be noted here that in the foregoing embodiments, although the TFT liquid crystal panel using TN liquid crystal has been described as used for the light valve, liquid crystal panels of other systems or panels using electro-optical crystals, etc. may also be used so far as they can form optical images as variation of optical characteristics.

DEPL:
where b is the distance from the focal point 81 of the first lens array means 71 to the principal point of the second lens array means 72, and c is the distance from the principal point of the second lens array means 72 to the pixel 74 of the light valve 73.

CLPR:
1. A light valve apparatus comprising:

CLPR:
2. A light valve apparatus as claimed in claim 1, wherein the pixels of said light valve are arranged in a square matrix pattern, and wherein an optical

axis of each of said microlens elements of said first lens array passes through a center of a square formed by connecting centers of four adjacent microlens elements of said second lens array.

CLPR:
3. A light valve apparatus as claimed in claim 1, wherein the pixels of said light valve are arranged in a square matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a middle point of a line segment connecting centers of two adjacent microlens elements of said second lens array.

CLPR:
4. A light valve apparatus as claimed in claim 1, wherein said light valve apparatus is adapted to satisfy a condition represented by an equation,

CLPR:
5. A light valve apparatus as claimed in claim 1, wherein the pixels of said light valve are arranged in a delta matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a center of a triangle formed by connecting centers of three adjacent microlens elements of said second lens array.

CLPR:
6. A light valve apparatus as claimed in claim 1, wherein the pixels of said light valve are arranged in a delta matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a middle point of a line segment connecting centers of two adjacent microlens elements of said second lens array.

CLPR:
7. A light valve apparatus as claimed in claim 6, wherein said light valve apparatus is adapted to satisfy a condition represented by an equation,

CLPR:
8. A light valve apparatus are claimed in claim 1, wherein said light valve is of a liquid crystal panel.

CLPR:
9. A light valve apparatus as claimed in claim 1, wherein said second lens array is formed on an emitting side face or in the vicinity of a surface of a first transparent substrate disposed at an incident side of said light valve, said third lens array is formed on an emitting side face or in the vicinity of a surface of a second transparent substrate disposed at an incident side of said second lens array means, said first lens array means being formed at an emitting side face or in the vicinity of a surface of a third transparent substrate disposed at an incident side of said third lens array.

CLPR:
10. A light valve apparatus as claimed in claim 1, wherein said second lens array is formed on an incident face side or in the vicinity of a surface of said light valve, said third lens array is formed on an incident side face or in the vicinity of a surface of a first transparent substrate disposed at an incident side of said light valve, and said first lens array is formed on an incident side face or in the vicinity of a surface of a second transparent substrate disposed at an incident side of said third lens array.

CLPR:
11. A light valve apparatus as claimed in claim 1, wherein said second lens array is formed on an incident side face or in the vicinity of a surface of said light valve, said third lens array is formed on an emitting side face or in the vicinity of a surface of a transparent substrate disposed at an incident side of said light valve, and said first lens array is formed on an incident side face or in the vicinity of a surface of said transparent substrate.

CLPR:
12. A light valve apparatus as claimed in claim 1, wherein said second lens array is formed, on an emitting side face or in the vicinity of a surface of a first transparent substrate disposed at an incident side of said light valve, said third lens array is formed on an incident side face or in the vicinity of a surface of said first transparent substrate, and said first lens array is formed on an incident side face or in the vicinity of a surface of a second transparent substrate disposed at an incident side of said third lens array.

CLPR:
13. A light valve apparatus as claimed in claim 1, wherein said second lens array is formed on an emitting side face or in the vicinity of a surface of a first transparent substrate disposed at an incident side of said light valve, said third lens array is formed on an emitting side face or in the vicinity of a surface of a second transparent substrate disposed at an incident side of said second lens array, and said first lens array is formed on an incident side face or in the vicinity of a surface of said second transparent substrate.

CLPR:
14. A light valve apparatus as claimed in claim 1, wherein said second lens array is formed on an emitting side face or in the vicinity of a surface of a first transparent substrate disposed at an incident side of said light valve, said third lens array is formed on an incident side face or in the vicinity of a surface of said first transparent substrate, and said first lens array is formed on an incident side face or in the vicinity of a surface of a second transparent substrate disposed at an incident side of said third lens array.

CLPR:
15. A light valve apparatus as claimed in claim 1, wherein an optical axis of each of the microlens elements of said third lens array is aligned with an optical axis of the corresponding microlens element of said first lens array.

CLPR:
16. A light valve apparatus as claimed in claim 1, wherein an optical axis of each of the microlens elements of said second lens array is aligned with an optical axis of the corresponding microlens element of said first lens array.

CLPR:
17. A light valve apparatus as claimed in claim 16, wherein said light valve apparatus is adapted to satisfy a condition represented by an equation,

CLPR:
18. A light valve apparatus as claimed in claim 2, herein said light valve apparatus is adapted to satisfy a condition represented by an equation,

CLPR:
19. A light valve, apparatus as claimed in claim 5, wherein said light valve apparatus is adapted to satisfy a condition represented by an equation,

CLPR:
22. A projection display system as claimed in claim 20, wherein the pixels of said light valve are arranged in a square matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a center of a square formed by connecting centers of four adjacent microlens elements of said second lens array.

CLPR:
23. A light valve apparatus as claimed in claim 20, wherein the pixels of said light valve are arranged in a square matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a middle point of a line segment connecting centers of two adjacent microlens elements of said second lens array.

CLPR:

24. A projection display system as claimed in claim 20, wherein the pixels of said light valve are arranged in a delta matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a center of a triangle formed by connecting centers of three adjacent microlens elements of said second lens array.

CLPR:
25. A light valve apparatus as claimed in claim 20, wherein the pixels of said light valve are arranged in a delta matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a middle point of a line segment connecting centers of two adjacent microlens elements of said second lens array.

CLPR:
28. A projection display system as claimed in claim 26, wherein the pixels of said light valve are arranged in a square matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a center of a square formed by connecting centers of four adjacent microlens elements of said second lens array.

CLPR:
29. A light valve apparatus as claimed in claim 26, wherein the pixels of said light valve are arranged in a square matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a middle point of a line segment connecting centers of two adjacent microlens elements of said second lens array.

CLPR:
30. A projection display system as claimed in claim 26, Wherein the pixels of said light valve are arranged in a delta matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a center of a triangle formed by connecting centers of three adjacent microlens elements of said second lens array.

CLPR:
31. A light valve apparatus as claimed in claim 26, wherein the pixels of said light valve are arranged in a delta matrix pattern, and wherein an optical axis of each of said microlens elements of said first lens array passes through a middle point of a line segment connecting centers of two adjacent microlens elements of said second lens array.

CLPV:
a light valve in which a plurality of pixels are arranged in a first matrix pattern;

CLPV:
a first lens array in which a plurality of microlens elements are arranged in a second matrix pattern similar to the first matrix pattern of the pixels of said light valve, and which is located at an incident side of said light valve; and

CLPV:
a second lens array in which a plurality of microlens elements are arranged in a third matrix pattern similar to the first matrix pattern of the pixels of said light valve, and which is located between said light valve and said first lens array;

CLPV:
a third lens array in which a plurality of microlens elements are arranged in a fourth matrix pattern similar to the first matrix pattern of the pixels of said light valve, and which is located between said first lens array and said second lens array;

CLPV:
wherein a focal length of each of the microlens elements of said first lens

array is equal to or shorter than a focal length of each of the microlens elements of said second lens array, the respective microlens elements of said second lens array being adapted to form real images of a virtual light source at focal points of said first lens array on the corresponding pixels of said light valve, and the respective microlens elements of said third lens array being adapted to form real images of the virtual light source at principal planes of the plurality of the microlens elements of said first lens array on principal planes of the plurality of the microlens elements of said second lens array.

CLPV:
a light valve apparatus upon which light emitted from said light source is incident and in which optical images are formed according to video signals; and

CLPV:
said light valve apparatus including:

CLPV:
a light valve apparatus upon which light emitted from said light source is incident and in which optical images are formed according to video signals;

CLPV:
said light valve apparatus including:

CLPW:
a light valve in which a plurality of pixels are arranged in a first matrix pattern;

CLPW:
a first lens array in which a plurality of microlens elements are arranged in a second matrix pattern similar to the first matrix pattern of the pixels of said light valve, and which is located at an incident side of said light valve; and

CLPW:
a second lens array in which a plurality of microlens elements are arranged in a third matrix pattern similar to the first matrix pattern of the pixels of said light valve, and which is located between said light valve and said first lens array;

CLPW:
a third lens array in which a plurality of microlens elements are arranged in a fourth matrix pattern similar to the first matrix pattern of the pixels arrangement of said light valve and which is located between said first lens array means and said second lens array,

CLPW:
wherein a focal length of each of the microlens elements of said first lens array is equal to or shorter than a focal length of each of the microlens elements of said second lens array, the respective microlens elements of said second lens array being adapted to form real images of a virtual light source at focal points of said first lens array on the corresponding pixels of said light valve, and the respective microlens elements of said third lens array being arranged to form images of the virtual light source at the principal planes of said respective microlens elements of said first lens array means on principal planes of the plurality of microlens elements of said second lens array.

CLPW:
a light valve in which a plurality of pixels are arranged in a first matrix pattern;

CLPW:
a first lens array in which a plurality of microlens elements are arranged in

a second matrix pattern similar to the first matrix pattern of the pixels of said light valve, and which is located at an incident side of said light valve; and

CLPW:
a second lens array in which a plurality of microlens elements are arranged in a third matrix pattern similar to the first matrix pattern of the pixels of said light valve, and which is located between said light valve and said first lens array;

CLPW:
a third lens array in which a plurality of microlens elements are arranged in a fourth matrix pattern similar to first matrix pattern of the pixels of said light valve, and which is located between said first lens array and said second lens array,

CLPW:
wherein a focal length of each of the microlens elements of said first lens array is equal to or shorter than a focal length of each of the microlens elements of said second lens array, the respective microlens elements of said second lens array being adapted to form real images of a virtual light source at focal points of said first lens array on the corresponding pixels of said light valve, and the respective microlens elements of said third lens array being arranged to form images of the virtual light source at the principal planes of said respective microlens elements of said first lens array means on principal planes of the plurality of microlens elements of said second lens array.

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DOCUMENT-IDENTIFIER: US 5428366 A
TITLE: Field sequential color illumination system for liquid crystal display

Abstract Text (1):
A field sequential color illumination system for liquid crystal displays is described which focuses light from a plurality of small point like or line like light sources into subregions of pixels of an LCD by a fly's eye lens, in such a manner that at any given time, red, blue, and green light spots are focused simultaneously into different pixels. Furthermore, during each subsequent field, light spots are focused into different sub sections of each pixel in such a way that each pixel receives red, green, and blue illumination sequentially during each set of three fields. During each field, each pixel is addressed and made to display the appropriate transmittance level to display the appropriate red, green, or blue color level for its location on the red, blue, or green color component of the image just prior to illumination of a sub region by a red, green, or blue light source.

Brief Summary Text (3):
The present Invention relates to a color liquid crystal display (LCD) system, and more particularly to illumination for liquid crystal display devices and field sequential color illumination for such devices in which said devices are illuminated by flashes of red, green, and blue light in sequence.

Brief Summary Text (5):
LCD technology has progressed rapidly in recent years. Most of the development effort has been directed toward TFT (thin film transistor) LCDs which have a transistor at each pixel. This allows one to regulate the amount of charge placed at the tiny capacitors located at each pixel, and thus precisely control the degree to which it turns on and off, in order to provide a gray scale. Such LCDs have very high contrast ratios, on the order of 100:1. The largest commercially available LCDs of this (or at the moment, any) type are about 15 inch (38 cm) on the diagonal. The highest resolutions available are about 640.times.480 pixels. The total numbers of colors that such LCDs can generate are in excess of 16 million with a suitable controller.

Brief Summary Text (6):
Although image quality of these LCDs is quite good in terms of contrast and color, their resolution and screen size make them suitable only for personal computer (PC) level applications. The industry is addressing both issues. The goal is the mass production of flat-panel LCD displays with at least the same quality as high-end cathode ray tube (CRT) displays.

Brief Summary Text (7):
Screen size is at present limited by the equipment required to manufacture the LCDs. The industry as a whole is introducing new systems that will allow the production of 14 inch (35 cm) and larger TFT LCDs. Sanyo, for example, produces a 16 inch (40 cm) diagonal black and white LCD. In the United States, UCE Inc. claims the ability to fabricate 1.4 meter diagonal passive STN LCDs, and is seeking to construct an advanced driving system to address and create images on such large LCDs.

Brief Summary Text (8):
Major difficulties remain with the reliable manufacturing of high resolution, high

quality TFT LCD plates with up to several million pixels, however. Various technologies are being developed to cope with the production problem. One solution has been to develop alternate technologies which can reduce the electronic complexity of the LCD. For example, the Sarnoff Research Institute recently demonstrated an LCD in which the pixel scanning electronics are integrated onto the glass plate along with the pixel transistors.

Brief Summary Text (9):
A subclass of this approach has been the development of field sequential color techniques that allow each pixel to do the work of three. This could avoid some of the difficulties associated with the manufacture of high resolution LCDs by using fewer pixels. When using a field sequential illumination scheme, a very fast black and white LCD is operated at 180 frames per second. Red, green, and blue lamps (such as strobe fluorescent lamps) are flashed sequentially behind the LCD. Before each color is flashed, the LCD is addressed and made to display the red, green, or blue component of the image, yielding one complete color image every 1/60th second. Since the eye cannot detect image changes at this speed, the observer perceives a nearly flickerless full-color image.

Brief Summary Text (11):
The Sarnoff Research Institute and several other companies are actively developing direct view and projection displays based on this method. Since it is relatively easy to create an LCD with many times the normal operating speeds of 60 frames per second (fps), this technique holds great promise. If this technology were combined with present state-of-the-art mass production techniques, color LCDs with resolutions in excess of 3,000,000 pixels could be manufactured.

Brief Summary Text (12):
US-A-5,036,385 describes a method whereby the resolution of a fast liquid crystal display can be increased beyond the total number of pixels on the display by sequentially focusing strobed light into sub regions of each pixel, while the LCD changes the state of the pixels to create intensity levels appropriate to the subregion locations on a high resolution image composed of the subregions, instead of the pixels themselves. Furthermore, the light focused into each subregion can be of different colors, and red, green, and blue light can be sequentially and repeatedly focused into different subregions to create color images composed of red, green, and blue color components.

Brief Summary Text (16):
In an electronic display utilizing an array of light valves, whose transparency can be individually controlled to form images, the improvement being a stroboscopic illumination system for the display comprising a plurality of light sources consisting of at least two sets of light sources, each set of light sources emitting light of a different color and the plurality of light sources also consisting of at least two groups, each group containing at least one member of each set; an electronic means for independently controlling the on and off states of the light sources in synchronization with the process of image generation on the electronically controllable light valve array, such that different groups of light sources are turned on, then off, in succession; an optical means for accepting the light emanating from the light sources and to focus the light into patterns of lines, line segments, or point like areas within or near the plane of the light valve array, the light patterns illuminating selected sub regions of the elements of the light valve array; the light sources, optics and on/off sequence`are so arranged that when any group of light sources is on, light of at least two colors emanating from members of different sets within that group is directed into subregions of different sets of light valves at the same time, so that light of different colors are being directed into different sets of light valves.

Drawing Description Text (2):
FIG. 1 is a magnified view of a section of an LCD, showing how different subregions of each pixel of the LCD can be illuminated in a certain temporal sequence.

Drawing Description Text (4):
FIG. 3 is a timing diagram illustrating the timing involved between the address of pixels on the LCD, the generation of images due to changes in pixel states after

address, and flashing of the various lamps in FIG. 2.

Drawing Description Text (5):
FIG. 4 diagrams an alternate illumination configuration using a large number of lamps and a suitable fly's eye lens to achieve the same effect as the illumination system in FIG. 2, but which occupies a smaller volume.

Drawing Description Text (6):
FIG. 5 diagrams the timing involved between the address of the LCD, changes in pixel states after address, and flashing of the various lamps shown in FIG. 4.

Drawing Description Text (7):
FIG. 6 is a magnified view of a section of an LCD illustrating how subregions of pixels can be illuminated by red, green, and blue light in a certain spatial pattern and in a certain temporal sequence.

Drawing Description Text (9):
FIG. 8 is a magnified view of an LCD showing an alternate spatial pattern of colored illuminated subregions that can be illuminated in a certain temporal sequence.

Drawing Description Text (11):
FIG. 10 is a magnified view of part of an LCD showing how a larger number of subregions in a certain spatial pattern can be illuminated within each pixel in a certain temporal sequence.

Drawing Description Text (12):
FIG. 11 is a magnified view of part of an LCD illustrating a larger spatial pattern of colored subregions within a larger number of pixels.

Drawing Description Text (13):
FIG. 12 is a magnified view of part of an LCD illustrating how linear subregions of pixels can be illuminated in a certain spatial pattern and in a certain temporal sequence.

Detailed Description Text (3):
In FIG. 1 four light emitting regions 1-4 are situated either near the liquid crystal (LC) layer of the display, or ideally are projected onto the plane of the LC layer by appropriate optics (an example of which will be described later). Light emitting regions 1-4 turn on and off in succession, so that first light 1 is turned on, then the first light 1 region turns off and the second light emitting region 2 turns on, and so on with the third and fourth light regions 3 and 4. When the first light region 1 is on, the transparency of each pixel 5 on the LCD is changed to provide the correct apparent brightness for each of the illuminating regions so that an observer sees an image composed of region 1. When the second light emitting region 2 is on, each pixel 5 again changes its transparency so that the observer sees different parts of the same image made up of region 2, and so on with the remaining light emitting regions 3 and 4. Thus, during each cycle, through each light emitting regions 1-4 a complete 2N.times.2N image is built up from the interaction of the N.times.N pixel LCD and the pattern of illuminating regions 1-4.

Detailed Description Text (4):
The increase in resolution that can be obtained using this method depends on the speed of the LCD. With proper sequencing of the illuminating regions, an LCD operating at N.times.30 frames per second can form almost flickerless images that have a total resolution N times greater than the LCD itself. Although the light emitting regions shown in FIG. 1 are squares arranged in a grid pattern, any shape and arrangement could in principle be used.

Detailed Description Text (5):
The method that is typically used to create light emitting points or lines within or behind each pixel is illustrated in FIG. 2. In FIG. 2, point-like light emitting sources 7, 8, 9 and 10 are placed behind a fly's eye lens sheet 11 consisting of a clear base such as a sheet of glass or plastic 12 with fly's eye spherical lenses 13 molded into one surface. The lenses 13 can be conventional refractive lenses or high quality diffracting or binary lenses. The lenses 13 are arranged in an array with

straight rows and columns. The curvature of each lenslet is such that it forms images of the light emitting sources 15-18 near or at the layer of liquid crystal material 14 within an LCD 6 mounted directly in front of the lens sheet 11.

Detailed Description Text (6):
The size and arrangement of the fly's eye lenslets is such that one lenslet is situated behind each pixel of the LCD, and thus forms images 15-18 of the four light emitters 7-10 within or slightly in front of or behind each pixel, as is shown in FIG. 2. It is also possible to focus the images of the light emitters 7-10 on to a diffuser placed on the side of the LCD 6 opposite the light emitters 7-10 in order to achieve even illumination. It is also possible to place a weak diffuser between the light emitters 7-10 and the LCD 6 to achieve the same purpose.

Detailed Description Text (7):
Although a small number of light emitting points or lamps 7-10 is shown in FIG. 2 for simplicity, there being one lamp for each set of light sources, in most embodiments an array of many light sources would be used. One advantage of a larger array consists of an ability to place the array closer to the LCD than a small number of lamps, since each light source can be used to illuminate just a small section of the LCD. This, of course, saves space. Another advantage lies in the ability to relax the address and pixel change speed requirements for the LCD compared to a system with few light sources. The reasons for the second advantage will become apparent from the discussion below.

Detailed Description Text (8):
An opaque flat black non-reflective barrier 56 blocks the area between and to the sides of light emitters 7-10, so as not to allow light to exit the sides of light emitters 7-10 or to be reflected from the light emitters 7-10 from points other than the light emitters 7-10. A system of baffles 54 consisting of opaque dividers or barriers extending out from the barrier 56 can be placed in the system as shown in FIG. 2 to prevent light from the light emitters 7-10 reaching points on the lens 12 far from the area directly in front of the light emitters 7-10.

Detailed Description Text (9):
It is generally desirable that the lens 12 have anti-reflective coatings 55 on their front most and rear most surfaces, that any non diffusing surface of a diffuser has an anti-reflective coating 55, and that the rear most surface of the LCD 6 have an anti-reflective coating 55.

Detailed Description Text (10):
The timing sequence of LCD scan (during which all pixels are addressed), pixel transmittance changes to form the next image component, and light source turn on and turn off when a small number of lamps is used, as in FIG. 2, is shown in FIG. 3.

Detailed Description Text (11):
The timing diagram of FIG. 3 is composed of graphs 3a, 3b, and 3c. Graph 3a depicts the repeated address of LCD rows starting at the top row and proceeding to the bottom row. Graph 3b shows the change from "off" or opaque state to "on" or clear state (or vice versa) of the first and the last pixels in a video field, after these pixels have been addressed, and the flashing of the first light emitting point or lamp 7 shown in FIG. 2. In the case of TFT and Ferroelectric LCDs, when a pixel is turned on during the scan of an LCD, it stays on until turned off, in this case until the scan of the entire LCD to display one video frame is completed, and the last pixels have had time to change their state.

Detailed Description Text (12):
As shown in graph 3a the time period between the start of one LCD scan and the start of the next is divided into three periods during which three actions occur: a first period 22 during which the LCD is scanned and its rows sequentially addressed usually starting at the top row 20 and ending at the bottom row 21 causing the pixels to change state in order to display the next image, a pause or waiting period 23 during which nothing happens, and an optional blanking period 24 of beneficial effect in some LCDs in which the LCD is scanned again and all the pixels are addressed and made to change state to either full on or full off. Typically, all the pixels of a given row are addressed at the same time.

Detailed Description Text (13):
The signal to change the states of the first row pixels is given to the LCD 6 at time t.sub.0. For illustrative purposes, it is assumed that a delay of about 2 ms occurs before the pixel completes its change to a new state in response to the applied signal--it begins to turn on at time t.sub.1 and completes the change in its state between opaque and clear at time t.sub.2 as shown in graph 3b. Although in graph 3b pixels are shown turning between full off and full on it is understood that typically some will be turning from on to off and others will turning between one intermediate gray state and another. The last pixel starts its state change at time t.sub.3 when it is addressed and completes it at time t.sub.4. At this instant the video frame is complete and the light source 7 flashes, as shown in graph 3c, thus transferring the information in the first field to the observer. As seen in graph 3a a pause period 23 during which no addressing of the LCD happens is inserted in order to give all the pixels time to change to their new state before the lamp is fired. If the time it takes a pixel to change state is long enough, or the time required for a scan is short enough, a second scan can occur during the pause period. During the second scan the same image information is transferred to the LCD as in the first scan. The optional blanking scan can then occur followed by the next address of the LCD during which the pixels are addressed in order to create the second image field. The sequence in the second frame is the same as in the first frame except that lamp 8 flashes. Likewise, the timing of events is identical in subsequent frames, the only difference being the information written to the LCD and which of the lamps flashes.

Detailed Description Text (15):
In the case of the system providing four times resolution increase illustrated in FIGS. 1-3, a total of 8.3 ms at most must elapse from the time the address signal has been applied to the first pixel to the completion of the change in state of the last pixel, the flash of the lamp, and the beginning of the next address of the first pixel. This allows 120 fields to be displayed per second or 30 complete, high resolution images displayed per second. A lesser number of images displayed per second would result in flicker being apparent, as has been confirmed experimentally with a system that increases the resolution of a ferroelectric LCD by a factor of four.

Detailed Description Text (16):
Again as shown in FIG. 3, the pixels take a certain period of time to change state once they are addressed. In this case 2 ms is shown for illustration, that being the period typical of a custom pixel LCD being made by an LCD development lab for Dimension Technologies Inc. The time required to turn off from full on may be different than the time required for full on to full off, or the time required to change between various intermediate gray levels. In such cases, the longest time period required to change between two states is most relevant, and must be accommodated so that all pixels, regardless of which states the change to or from, can complete their change before a lamp is fired.

Detailed Description Text (17):
Lamps, of course, never flash instantaneously, but rather emit light for a short time and then turn off. The duration that the lamp is emitting light depends on the lamp, and can be controlled with some lamps, such as LEDs. In general, the lamp should emit light only during the time period between the completion of the last pixel's change and the beginning of the next address scan. However, if a blanking scan is used, and the LCD is blanked to a dark state, the lamps may emit light during the blanking period without significant image degradation. However, if the LCD is blanked to the bright or transparent state, the lamps should stop emitting light before the blanking period begins. Otherwise, contrast will be lessened considerably.

Detailed Description Text (18):
FIG. 4 shows a configuration using an array 30 of a large number of light sources placed at a shorter distance behind the fly's eye lens sheet 11 and LCD 6. FIG. 5 is a timing diagram showing how lamps in different rows of the array are turned on and off in synchronization with LCD scans and pixel changes.

Detailed Description Text (19):
The array shown in FIG. 4 has 8 rows of light source groups 31-38. Each group consists of four light sources 39-42. Each row of light source groups illuminates a horizontal section of the LCD 43-50 of roughly 1/8th the LCD's height. The LCD is assumed to be addressed row by row, starting from the top, as is typical of LCDs. Since each light source only illuminates a 1/8th horizontal section of the LCD, one must wait only for the pixels in a given 1/8th section to be addressed and complete their change before turning on the lamps behind it.

Detailed Description Text (20):
For example, in FIG. 5 the address and pixel response of the last rows of sections 43-50 are shown in FIGS. 5a and 5b. Again, the LCD is operated at 120 times per second, and the pixels take 3.5 ms to respond. As soon as the pixels of the last row of section one are through changing, the lamps marked 39 in the row of lamp groups 31 in FIG. 4 are turned on. Their brightness curve 31 is shown in graph 5c. They may remain on until the first rows of section 43 are addressed again, and start changing. Graph 5c shows the lamps turning off at this point in time. The light from these lamps is imaged by the fly's eye lens into the upper left quadrants of each pixel. Likewise, as soon as the pixels of section 44 are through changing, the lamps 39 of row 32 are turned on. These, likewise do not turn off until the first row of section 44 is addressed again. The address and turn on sequence continues for section 45-50.

Detailed Description Text (21):
After the last section 50 is addressed, the scan can immediately proceed to address the LCD again, starting at the top. The lamps behind section 43, of course, will ideally turn off before the next scan of section 43 begins. After the first section 43 is addressed again, and its pixels have had a chance to change, lamps 40 in row 31 are turned on, providing illumination to the upper right hand quadrants of the LCD pixels of section 43. The remaining lamps 40 of rows 32-38 turn on in succession, as the pixels of the sections 44-50 in front of them complete their change to a new transparency state.

Detailed Description Text (23):
The main advantage of this embodiment of this invention is that the time required for the wait frame or pause period, where one is waiting for all the pixels, including the very last ones, to complete their change is greatly shortened. Each of the smaller sections is illuminated as soon as the pixels within that section complete their change, which may occur while another part of the LCD is still being addressed. Indeed, if the pixels can complete their change in a period of time less than the interval between the address of the last column of their section and the next address of the first column of their section, as is the case in the timing diagram of FIG. 5, the LCD can be addressed continuously, without any pause at all between fields.

Detailed Description Text (24):
Also, given the arrangement of FIG. 5, the lamps do not necessarily have to flash in a very short interval. They can remain on for the duration of the period between the time when the pixels of the last addressed column of the section in front of them complete their change to the time when the pixels in the first addressed column are addressed again during the next scan. In the case of ferroelectric LCDs, with pixel response times of much less than 1 ms, a given lamp may remain on for the most of the time between subsequent scans of the section in front of it. This can result in a brighter display, since each lamp remains on for a greater fraction of the total time.

Detailed Description Text (25):
Although FIG. 4 shows four sets of light sources arranged in groups of four lamps each, it is understood that any number of light sources or groups of light sources, constrained in their number only by the physical dimensions of the display, the dimensions of the light sources themselves, and the address and pixel response speed of the LCD, could be used in this illumination scheme.

Detailed Description Text (26):
If an array of more than one set of light sources is used, it will usually be

necessary to diffuse the light coming from it in order to create even illumination. This can be accomplished by the use of a weak diffuser 51 as shown in FIG. 4 situated between the array and the lenticular or fly's eye lens. A weak diffuser placed on or near the front of the LCD will also work. An alternative lens configuration can be used to focus light beyond the pixel layer onto a diffuser located in front of the LCD.

Detailed Description Text (27):
Of course, if the light sources in FIG. 4 are of different colors, particularly if they are red, green, and blue, then a color image can be built up by sequentially flashing the red, green, and blue sources either all together or following the scan of the LCD as explained above. For example, in FIG. 4 lamps 39 might be red, lamps 40 and 41 green, and lamps 42 blue. In that case, light regions 1 would be red, regions 2 and 3 would be green, and regions 4 would be blue--resulting in a quad arrangement of colored subregions similar to that used on some existing LCDs that employ colored filters over each pixel. The same timing sequences described above would apply. However, note that with that particular color arrangement, both green lamps could turn at the same time.

Detailed Description Text (28):
Such a flashing sequence, will, however, lead to the same type of image breakup phenomena seen in other field sequential color displays. It is also believed this would necessitate a much faster address speed and pixel response speeds for the LCD, as is the case with existing field sequential color systems. This is because in order to avoid flicker one would undoubtedly have to create a compete image every 1/60th as opposed to 1/30th second, as is the case with other field sequential color systems that illuminate the whole LCD first with red, then green, then blue light. That means that the LCD must be capable of generating 180 completely different images every second, so that, a red, a green, and a blue image component are presented every 1/60th second.

Detailed Description Text (29):
The illumination sequence used to overcome the image breakup phenomena relies on the ability of this invention's field sequential color illumination system to multiplex the illumination spatially as well as temporally. This ability should also allow one to operate the LCD and illumination system at much lower speeds--possibly as low as 30 complete images per second--without flicker becoming visible. The reason for this is that a line interlaced image can be created in which members of a set of three lines of red, green, and blue image elements is flashed sequentially.

Detailed Description Text (32):
FIG. 6 shows one of several interlace configurations that can be generated with this type of optics. This particular pattern is closest to the typical CRT row interlace scheme and therefore good for illustrative purposes. The figure shows a magnified view of two representative row of pixels on an LCD. During the first /90th second, the LCD is scanned and the pixels in columns 60, 63, 66, etc., are made to change their transparency to display part of the red component of an image. Pixels in columns 61, 64, 67, etc., are made to change their transparency to display part of the green component of an image, and pixels in columns 62, 65, 68, etc., are changed to display parts of the blue component of an image.

Detailed Description Text (36):
Note that in this case each group of three red, green, and blue spots in each row is being used as a complete image pixel, in a manner similar to a typical color LCD with color filter stripes.

Detailed Description Text (38):
In this example, if the LCD had a pixel resolution of M (horizontal) by N (vertical), the resolution of the image would be M/3.times.3N--the total number of pixels would be the same in image and LCD, but the ratio of horizontal to vertical resolution would be different. It would be best in such a case to start out with pixels that had a high ratio (as shown) between their vertical and horizontal dimensions.

Detailed Description Text (39):

Another option, achieved using an illumination pattern similar to that shown in FIG. 8 allows each pixel to be illuminated by red, green and blue light in succession and thus allows each pixel on the LCD to represent a pixel on the image. In such a case each pixel would represent one element of a M.times.N image, and would change its transmittance to reflect the intensity of red, green, and blue light at that point as the red, green, and blue light illuminated subregions of it.

Detailed Description Text (41):
FIG. 7 shows the type of illumination array 57 and fly's eye lens 58 arrangement that could be used to generate the light patterns shown in FIG. 6. FIG. 9 shows the type of illumination array 57 and lens 58 that can be used to generate the light patterns shown in FIG. 8. A fly's eye lenslet is configured so that each lenslet is situated behind a group of pixels where the entire repeating pattern is to be focused. For example, if the pattern repeats in every group of three pixels, as in FIG. 7, lenslets of roughly the same size as a group of three pixels must be used, and placed behind every group of three.

Detailed Description Text (43):
As before, the elements of each set on the illuminator could be made to turn on and off sequentially from top to bottom, following the scan of the LCD. If the illumination of FIG. 7 had 8 rows of 3.times.3 patterns, ,8 sections of the LCD would be illuminated sequentially. In the figure, the lamps 80, 81, 82 would turn on during the first scan, to illuminate the bottom 1/3 of each pixel. Lamps 83, 84, 85 would turn on during the next scan to illuminate the middle third of each pixel, and lamps 86, 87, 88 would turn on to illuminate the top third of each pixel.

Detailed Description Text (45):
Although three rows of illuminated sub regions of each pixel are shown in FIGS. 6 and 8, that number can be greater than three. By using greater numbers of subregions, the color image created can posses a resolution greater than the pixel resolution of the LCD. FIG. 10 is a diagram showing six lines of subregions 100-105 within each pixel which are illuminated sequentially, starting rows 100 and proceeding through rows 105. Given an LCD with N.times.N resolution, this arrangement would produce a color image with N.times.2N resolution.

Detailed Description Text (46):
Of course, if more subregions are used, a faster LCD must be used to avoid flicker, since more image sub components must be illuminated sequentially during the 1/30th second period. It is suspected, also, that as the number of subregions in each pixel increases, the overall frame speed, the time in which an entire image is built up, must be shortened. At the extreme end, a very large number of sequentially illuminated sub regions within large pixels may require a frame speed of around 1/60th second, since the visual impact will start to approach that of a none interlaced CRT, which has to be operated at 60 fps to avoid flicker.

Detailed Description Text (48):
In some situations, it may be desirable to use an illuminator consisting of a one dimensional array of linear light sources. The most common type of illumination used for LCDs, namely fluorescent tubes, are most often configured as long, thin tubes and cannot be made as small point like sources. Fluorescent tubes that emit red, green, and blue light can be made and easily mounted next to one another in banks. They can also be made to emit light in short bursts.

Detailed Description Text (49):
In the case of linear light sources, operating behind a typical LCD, it is best to mount them horizontally so that the members of each set can flash sequentially from top to bottom, following the scan of the LCD rows in front of it. Of course, if the LCD is scanned from side to side column by column, then the tubes should be mounted vertically.

Detailed Description Text (52):
After the LCD has been re-scanned and the pixels allowed to change their state again, a green line is flashed into the rows of pixels 120, a blue line into rows 121, and a red line into pixel rows 122. Again, pixels in each given row have the states appropriate to the color appearing in them. At the end of the next scan,

after a new partial image has been generated on the LCD, a blue line is flashed into the pixel rows 120, a red line into the pixel rows 121, and a green line into the pixel rows 122.

Detailed Description Text (54):
FIG. 13, a side view, shows the lamp and lens arrangement that can be used to generate the line pattern and sequence of FIG. 12. A bank of linear lamps is mounted with red, green, and blue light emitting members placed vertically in the order shown. A lens sheet is mounted behind the LCD as before, with its lenslets ideally of about one focal length away from the pixel layer. When using linear light sources, one has the option of using a lenticular lens in place of the fly's eye lens discussed previously. A lenticular lens is generally easier and less costly to make than a fly's eye lens of the same size. The lenticular lens would possess an array of cylindrical lenslets spaced across its surface, parallel to the length of the linear light sources. Such a lens is shown in FIG. 13.

Detailed Description Text (55):
In either case, each lens must image light into three pixels, although in some configurations the lens may image light into more than three pixels. The lenses and the light sources must be of the correct size and spacing relative to one another so that each lens images light from each set of red, green, and blue lamps into the correct pixels.

Detailed Description Text (56):
The lamps are turned on in the following order in succession, as soon the section of the LCD in front of them has been addressed and its pixels have completed its change to their required states. Each lamp turns off a certain time period after turn on, so that it is completely off by the time the next address occurs. The lamps 130 turn at the same time to form the first set of light lines 110. Lamps 131 turn on after the next scan and pixel change to form the lines 111. Lamps 132 turn on at the same time to form lines 112.

Detailed Description Text (58):
Various types of flashing light sources can be used to provide illumination for the displays of this invention including fluorescent lamps, gas filled arc lamps, gas filled plasma discharge devices, light emitting diodes, electroluminescent devices, electron excited phosphor displays such as cathode ray tubes, plasma displays, fluorescent displays and various steady light sources with light transmission controlling means such as arrays of liquid crystal light valves placed in front of them.

Current US Original Classification (1):
345/102

CLAIMS:

1. A device for displaying an image by sequential, multi-monochromatic color illumination, comprising:

an illuminator including a plurality of different monochromatic light sources for producing a plurality of different monochromatic colors of light;

an array of light valves located in front of the illuminator and in optical alignment therewith;

an electronic controller connected to the illuminator for setting each of the plurality of different monochromatic light sources in one of an on and an off state and for spatially and temporally multiplexing the plurality of different monochromatic colors;

a lens sheet disposed between the illuminator and the array of light valves for imaging the plurality of different monochromatic light sources in a plane adjacent the light valve array in which at least a portion of each of the light valves is illuminated by any one of the plurality of different monochromatic colors during a first illumination period in which all of the colors are displayed by the plurality